Tibial Plateau Fractures

Elsøe, Rasmus

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INCIDENCE, RADIOLOGICAL, FUNCTIONAL AND PATIENTREPORTED OUTCOMES

BY
RASMUS ELSØE

DISSERTATION SUBMITTED 2016

AALBORG UNIVERSITY
DENMARK

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Dissertation submitted

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PhD supervisor: Associate Prof. Ph.D., Sten Rasmussen,
Aalborg University Hospital

Assistant PhD supervisor: Associate Prof. Ph.D., Svend Erik Østgaard,
Aalborg University Hospital

PhD committee: Associate Professor Søren Peter Eiskjær (chairman)
Aalborg University Hospital

Professor Jes Bruun Lauritzen
University of Copenhagen

PhD, Head of orthopaedic trauma surgery
Gunnar Birkelund Flugsrud
Oslo University Hospital

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ENGLISH SUMMARY

The aim of the present PhD thesis was to report the incidence of tibial plateau fractures (Study I) and the short-term outcomes in bicondylar tibial plateau fractures treated with a circular external fixator (Studies III and IV). A further aim was to report the short-term outcomes in lateral tibial plateau fractures treated with bone tamp reduction and percutaneous screw fixation (Study II).

This thesis included a population based study of patients treated for a tibial plateau fracture, a retrospective cross-sectional study of patients treated for a lateral tibial plateau fracture and two prospective follow-up cohort studies on the treatment of complex tibial fractures.

This PhD thesis reported an incidence of tibial plateau fractures of 10.3/100,000/year in a complete Danish regional population.

The results reported that patients treated for a lateral tibial plateau fracture with bone tamp reduction and percutaneous screw fixation achieved a satisfactory level of radiological outcomes and a level of health related quality of life (Eq5d) below but not significantly different from the Danish reference population at a mean of 5.2 years follow-up. Furthermore, a knee injury-specific questionnaire (KOOS) reported a level of disability close to a reference population with only the subgroup Sport significantly below the age matched reference population.

The thesis reports a level of health related quality of life (Eq5d) and disability (KOOS) significantly below established reference populations for patients with bicondylar tibial plateau fracture treated with a ring fixator, both during treatment and at 19 months following injury.

In general, the thesis demonstrates that the treatment of tibial plateau fractures are challenging and that some disabilities following these fractures must be expected. Moreover, the need for further research in the area, both with regard to surgical treatment modalities, and combining surgical interventions with social science and rehabilitation is necessary.

DANSK RESUME

Formålet med denne Ph.d. afhandling var at rapportere incidensen af tibia plateau frakturer (Studie I) samt resultaterne på kort sigt af bikondylære tibia plateau frakturer behandlet med ringfiksator (Studie III og IV). Et yderligere formål var at rapportere resultaterne på kort sigt for laterale tibia kondyl frakturer behandlet med opbankning og perkutan skruefiksation.

De fire studier der afrapporteres i denne Ph.d. afhandling er et populationsbaseret epidemiologisk studie af patienter med tibia kondyl frakturer, et retrospektivt tværsnitsstudie af patient med laterale tibial kondyl frakturer samt 2 prospektive opfølgningsstudier omhandlende behandlingen af komplekse tibia frakturer.

Denne Ph.d. afhandling rapporterer en incidens af tibia plateau frakturer på 10,3/100.000/år i en komplet regional dansk befolkningsgruppe.

Resultaterne i denne afhandling antyder at patienter behandlet for en lateral tibia kondyl fraktur med opbankning og perkutan skruefiksation opnår et tilfredsstillende radiologisk resultat og en helbredsrelateret livskvalitet (eq5d) under, men ikke signifikant forskellig fra, en dansk reference gruppe ved 5,2 års opfølgning. Med et strukturspecifikt spørgeskema (KOOS) rapporteres et niveau af funktion tæt på referencepopulationen, hvor kun undergruppen sport ligger signifikant under en aldersmatched reference gruppe.

Resultaterne tyder endvidere på, at patienter behandlet for bikondylære frakturer med ringfiksator, udviser signifikant dårligere niveau af helbredsrelateret livskvalitet (Eq5d) og struktur specifikt funktionsniveau sammenholdt med referencegrupper, både under behandlingen frem til rammefjernelse og 19 måneder efter frakturtidspunktet.

Generelt understøtter denne afhandling at behandlingen af tibia plateau frakturer er udfordrende, og at man må forvente funktionsnedsættelse efterfølgende. Der er behov for yderligere forskning i området, både hvad angår den kirurgiske behandling, men også tværfaglig forskning involverende de kirurgisk modaliteter, socialvidenskaben og rehabiliteringen af denne patientgruppe.

ACKNOWLEDGEMENTS

Research is seldom a lonely task and the research performed to enable this PhD thesis is no different. I would never have been able to accomplish this work without the help of a vast amount of people.

First, I would like to thank all the patients who have spent numerous hours participating in the data collection of these studies. Secondly, I would like to thank all my colleagues at the Department of Orthopaedic Surgery, Aalborg University Hospital for helping in the collection of data and for the many great research discussions and laughs during my years as a PhD student. I would especially like to extend my gratitude towards Christian Pedersen, for allowing me the time to pursue this goal. I would also like to extend my gratitude to the Department of Physiotherapy for always being willing to help in every aspect of the research process. Without your flexibility and helpfulness, this work would not have been possible.

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I am sincerely grateful to my very good friend and colleague Peter Larsen who introduced me to the area of research and has provided invaluable support and help in every aspect of the research process. Thank you for always taking the time to help in every way. Thank you for the many hours of hard work and good fun we have shared and for being a good friend.

Finally, of course, I am grateful to my family for their love and support.

PREFACE

Data from the Trauma Ilizarov Database (TID) founded study III and IV. Data collection and the remaining scientific work was performed from December 2013 to February 2016 during my time as a PhD student at the Department of Clinical Medicin, Aalborg University hospital.

The PhD dissertation is based on the following four manuscripts:

I: Elsoe, R., Larsen, P., Hostrup Nielsen, N., Swenne, J., Rasmussen, S., Ostgaard, S. E. Population-based epidemiology of tibial plateau fractures, ORTHOPEDICS, 2015

II: Elsoe, R., Larsen, P., Shekhrajka, N., Ferreira, L. S., Ostgaard, S. E., Rasmussen, S. The outcome after lateral tibial plateau fracture treated with percutaneous screw fixation show a tendency towards worse function outcome compared with a reference population. European Journal of Trauma and Emergency medicine, 2015

III: Elsoe R., Kold S., Larsen P., Petruskevicius J., Treatment of complex tibial fractures with ring fixator. A Prospective observational study of 56 patients. Strategies in trauma and limb reconstruction (In review)

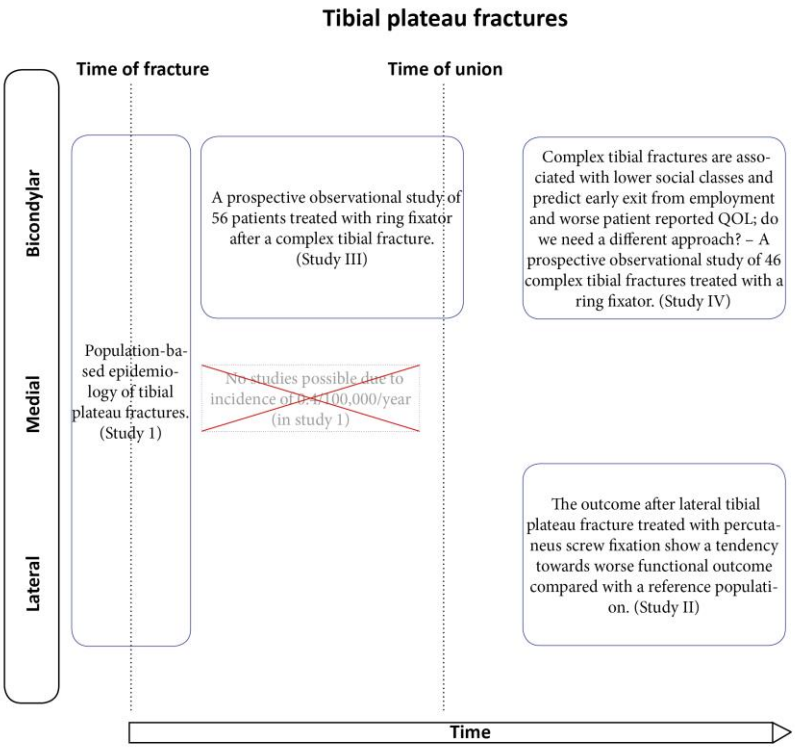
IV: Elsoe R., Larsen P., Petruskevicius J., Kold S., Complex tibial fractures are associated with lower social classes and predict early exit from employment and worse patient-reported QOL; do we need a different approach? – A prospective observational study of 46 complex tibial fractures treated with a ring fixator. Strategies in trauma and limb reconstruction (In review)

THESIS AT A GLANCE

Study	Purpose	Design	Patients	Primary Outcome	Conclusion
1	To describe the incidence of tibial plateau fracture in a large population and report the fracture classification distribution, trauma mechanism and patient baseline demographics.	Retrospective study of clinical and radiological records.	355 patients treated for a tibial plateau fracture in North Denmark region in a six-year period between 2005 and 2010.	Incidence of tibial plateau fractures	The incidence of tibial plateau fractures was 10.3/100.000/year. Both genders present the highest frequency between the ages of 40 and 60.
2	To evaluate the functional and radiological outcome after lateral tibial plateau fractures treated with minimal invasive bone tamp reduction and percutaneous screw fixation.	Retrospective cross-sectional study	37 patients treated for a lateral tibial plateau fracture between 2005 and 2010.	KOOS	Patients with lateral tibial plateau fractures treated with bone tamp reduction and percutaneous screw fixation at a mean of 5.2 years follow-up showed significant difference in one of five KOOS subscales (Sport) compared to a reference population.
3	To report the patient-reported quality of life (HRQOL) from surgery to eight weeks after	Prospective cohort study	29 patients treated between December	Eq5d-5L index	Patients treated for a bicondylar tibial plateau fracture treated with a ring fixator demonstrates a

	frame removal following a bicondylar tibial plateau fracture		2012 and May 2014		level of QOL (Eq5d) and disability (KOOS) significantly below established reference populations, both during treatment and at 8 weeks following union and removal of the circular frame.
4	The primary aim of this study was to report the patient-reported health related quality of life (HRQOL) at 12 months after frame removal following a bicondylar tibial plateau	Prospective cohort study	24 patients treated between December 2012 and May 2014 completed the examination.	Eq5d-5L index	Patients treated for a bicondylar tibial plateau fracture treated with a ring fixator demonstrates a level of QOL (Eq5d) and disability (KOOS) significantly below established reference populations, at 19 months following injury.

THE AREA OF THE THESIS



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ABBREVIATIONS

ORIF – Open reduction Internal Fixation

HRQOL – Health Related Quality Of Life

QOL – Quality Of Life

ROM – Range Of Motion

KOOS – Knee Injury and Osteoarthritis Outcome Score

VAS – Visual Analogue Scale

SD – Standard Deviation

CT- Computer Tomography

95%CI – 95% Confidence Interval

n – number

TKA - Total Knee Arthroplasty

DNPR – Danish National Patient Register

CPR – Central Person Register

ICC – Inter Class Correlation

WORMS – Whole-Organ Magnetic resonance imaging Score

AO - Arbeitsgemeinschaft für Osteosynthesefragen

WOMAC – Western Ontario and McMaster Universities Osteoarthritis Index

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CHAPTER 1. BACKGROUND

1.1. BRIEF HISTORIC PERSPECTIVE

As early as 1822 Sir Ashley Cooper described fractures of the proximal tibia[1]. In 1929 the lateral tibial plateau fracture was described as a "bumper" and "fender" fracture by Cotton and Berg[2], which reflects the general assumption at the time that the fracture was primarily caused by jay-walking[2]. The recognition of the fracture frequently being caused by falls was first developed in the decade following the second world war[2]. The treatment of these fractures by closed reduction and cast was the most common practice in the 1950s although Perey et al.[3] described open reduction and fixation with a screw in the more severe cases as early as 1952. The importance of anatomical reduction of the joint surfaces, rigid fixation and early mobilisation, to attain the goal of preventing post-traumatic osteoarthritis, was frequently advocated in the literature from the early 1950s and onwards[3–5]. Following the work by Danis and Müller in the 1950s[6] ORIF (Open Reduction Internal Fixation) became a popular treatment modality among surgeons[6]. At the same time Prof. Ilizarov's development of a circular external fixator offered new possibilities for the treatment of fractures[7]. Both treatment modalities were refined during the following decades, until the advent of the more advanced external fixators in 1990 utilising a hexapod design[8]. In the same time period the advent of pre-contoured, less invasive locking plates also gave promise of advances in treatment[8]. At present screws, plates, and external circular fixator are all used in the treatment of tibial plateau fractures and no treatment modality seems superior[9].

1.2. EPIDEMIOLOGY

Tibial plateau fractures are an uncommon injury and constitute approximately 1% of all long bone fractures[10–14]. Incidence has been reported between 13/100,000/year and 26/100,000/year with a substantial variation in time and geography[10–12,15]. Evidence suggests that the incidence is changing quickly because of underlying changes in trauma mechanisms and population demography with an increasing ageing population[10]. Tibial plateau fractures have been reported with a bimodal distribution[10] with peaks in the younger and older age groups for both genders with an even gender distribution[15]. The average age at the time of fracture has been reported between 44.5 years and 54.5 years in recent studies[14,15].

The fracture distribution according to the AO classification[16] has been reported by Albuquerque et al.[14]. AO type 41-B3 and 41-C3 fractures has been reported as the most common fracture types, representing 57% of all tibial plateau fractures. Unicondylar fractures account for approximately two-thirds of all tibial plateau

fractures[14]. Open fractures have been reported with a frequency of approximately 17% [17].

Low-energy falls have been reported as the predominant mode of injury in the unicondylar fractures and bicondylar fractures in the elderly[18]. High-energy trauma has been reported as the predominant mode of injury in the complex bicondylar fractures in the younger age groups where road traffic accidents in conjunction with falls from a height accounts for most fractures[9]. The incidence of tibial plateau fractures admitted as multitrauma patients has been reported in the literature between 16% and 41%[19,20].

The literature lacks recent, well defined population-based studies describing the incidence, fracture classification and mode of injury including all age groups. Furthermore, no Danish studies exist.

1.3. CLASSIFICATION

The ideal classification system should be reliable, reproducible, all-inclusive, mutually exclusive, logical, and clinically useful[21]. Several classification systems describing tibial plateau fractures have been proposed[22]. Two major classification systems are commonly used[5,16]. The oldest and most widely cited is the Schatzker classification[5] followed by the more recent AO classification[16], which has been chosen in this thesis. Both classification systems are reported to have moderate inter-observer reliability but excellent intra-observer reproducibility[22]. The inter- and intra-observer variability has been shown to improve greatly when CT scans are used in conjunction with standard X-rays[23].

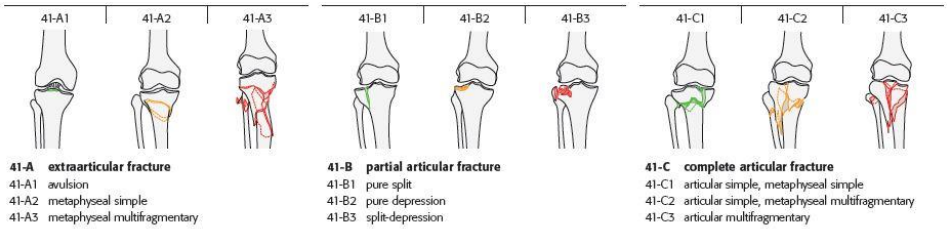

Figure 1-1AO classification: Reproduced from AOfoundation.org

1.4. TREATMENT OPTIONS

Treatment of tibial plateau fractures is challenging[24–27]. The treatment of tibial plateau fractures includes a variety of modalities ranging from brace/cast to percutaneous fixation, ORIF and external fixation[18,20,25,28–32]. Conservative treatment, usually restricted to simple, undisplaced fractures, is only possible in a small number of fractures[28]. The objective of surgery is the restoration of the plateau surface through anatomical reduction, rigid fixation, and early joint mobilisation[28] while maintaining the integrity of the soft tissue envelope[33]. The pattern of injury depends on the forces applied through the proximal tibia, the bone quality and the age of the patient, which all have an influence on the choice of treatment[33]. The best way to accomplish the goal of restoring the plateau surface while preserving mobility and soft tissue is elusive, especially in the most severe cases where patients in general have a poor outcome with persistent local symptoms[33].

1.4.1. LATERAL TIBIAL PLATEAU FRACTURES – SURGICAL OPTIONS

The different methods of surgical management of lateral tibial condylar fractures has been discussed frequently in the literature[18–20,25,29,31,32] including screw fixation, ring fixation, locking plates, grafting, with open or closed reduction[18–20,25,29,31,32,34,35]. There has been a trend towards treating pure depression fractures with a raft screw construction and those with significant comminution with a buttress plate, especially following the developement of locking plates[36]. However, the literature does not favour a single surgical method regarding radiological, functional and patient-reported outcomes.

1.4.2. BICONDYLAR TIBIAL PLATEAU FRACTURES – SURGICAL OPTIONS

Previously, the standard treatment of choice for bicondylar fractures has been ORIF through an extensive anterior incision[33,37]. Surgical management methods at present include ORIF[30], angle-stable locking plates[31], external fixators[25] and percutaneous screw fixation[29] and combinations of these[25,29].

Whereas ORIF has been criticised for its high infection rates[38], external fixation is claimed to be disadvantageous in severe comminuted fractures, especially those involving the posterior wall, and is reported to compromise alignment[39].

Open reduction internal fixation through an extensive soft tissue dissection was previously the standard treatment[33,37]. However, this treatment option is often complicated by wound breakdown and infection, with frequencies varying between

20% and 80% [18,33,38,40]. With the advent of periarticular locking plates the possibility of applying more minimally invasive techniques and hence sparing the soft tissue was achieved in conjunction with the possibility of obtaining secure fixation of the fragments[33], which may cause a reduction in infection rates[41].

Advances in modern circular frames have reduced the risk of malalignment and offer to possibility of performing intra- and postoperative correction with considerable ease compared to previous circular frames [8]. However, the literature does not favour a single surgical method regarding radiological, functional and patient-reported outcomes[8,17,33], and only a single randomized trial comparing ORIF with the circular fixator is available[17].

1.5. INITIAL COMPLICATIONS

Initial treatment complications has been largely related to damage to the soft tissue envelope[18]. A high rate of complications including skin necrosis and infection has been reported between 20% and 80%[18].

Several other complications following fracture or treatment have been reported[9,19,20,31]. Compartment syndrome has been reported in up to 23% of patients in a mixed group of unicondylar and bicondylar fractures[19]. Other complications such as deep vein thrombosis, non-union, myositis ossificans, peroneal nerve palsy, hardware failure and arthrofibrosis have all been reported with rare but varying frequencies[9,20,31].

1.6. OUTCOMES

1.6.1. RADIOLOGICAL OUTCOME

The incidence of post-traumatic osteoarthritis varies greatly in both short- and long-term follow-up studies[4,17,42]. Mehin et al.[42] reported a 13% incidence of knee osteoarthritis at 10-years follow-up in a combined uni- and bicondylar group of patients. Evidence of knee osteoarthritis in up to 25% of cases at 29 months follow-up has been reported in a mixed group of uni- and bicondylar fractures[19]. A study by McKee et al.[17] on bicondylar fractures reported an increase in knee osteoarthritis from 33% at one-year follow-up to 36% at two years follow-up, and incidences as high as 83% have been reported by a single author[28]. This marked increase in the risk of knee osteoarthritis following af tibial plateau fracture may lead to the need for secondary surgery such as TKR[43]. A recent study by Wasserstein et al.[44] reported the likelihood of receiving a TKR following a tibial plateau fracture to be five times higher than in

the general population. The same study also reported a likelihood of 7.3% of receiving a TKR within 10 years after a tibial plateau fracture[44].

1.6.2. PATIENT-REPORTED OUTCOMES

Patient-reported outcomes following a fracture of the tibial plateau have been addressed by a number of authors[8,9,17,25,28,33,45]. Most recent studies have included the use of generic health questionnaires such as SF-36, SF-12 and Eq5d. Ahearn et al.[33] reported significant functional deficit in the SF-36 health questionnaire in the short- and medium- term in a patient group with bicondylar fractures. Similarly, McKee et al.[17] reported a significant decrease in all SF-36 domains in a group of bicondylar fractures at two years follow-up. In contrast, patients with unicondylar fractures have been reported with no significant difference from a standardised Eq5d-5L reference population at a mean of one year follow-up[25,45] and 2.5 years' follow-up[25,45]. Stevens et al.[46] reported no significant difference in SF-36 scores in a mixed uni- and bicondylar patient group, compared with a reference population, at a minimum of 5 years follow-up.

Knee injury-specific questionnaires have been developed to address questions regarding symptoms following lesions or degenerative disease in a specific region[47]. McKee et al. reported a significant decrease in WOMAC score at two-year follow-up on bicondylar fractures. Supporting this, Elsoe et al.[45] reported a significant decrease in three of five KOOS subscales compared with a reference population treating lateral tibial plateau fractures with a mean follow-up of 2.5 years. Other studies have included knee injury-specific questionnaires in the evaluation of different treatment options, but do not compare outcomes with established reference populations[28,33,46]. To the authors knowledge, only two studies have compared a knee injury-specific questionnaire to reference populations following laterale tibial condyle fractures[45,48].

Most studies evaluating short- and long-term patient-reported outcomes following tibial plateau fractures, were conducted on mixed populations including both uni- and bicondylar fractures[19,25,49,50]. Furthermore, most studies are retrospective [28,33,41,46,49] and only a small number of studies includes both generic- and symptom-specific patient-reported outcomes[17,25,46] and the use of reference populations is rare[17,45,48].

Several studies have addressed the importance of surgical methods, the level of alignment, residual incongruity and the progression of osteoarthritis with regards to patient-reported outcomes following a tibial plateau fracture[8,9,17,25,33,50]. A single randomised controlled study[17] reported on surgical methods and found no significant difference in SF-36 and WOMAC scores when treating bicondylar tibial plateau fractures with either circular frames or plates.

Authors have argued that patient-reported outcome is not just dependent on the restoration of the articular surface, but to a large extend dependent on other factors such as the status of the soft tissue and the stability following surgery[33,46].

CHAPTER 2. AIMS OF THE THESIS

The aim of the present PhD thesis was to report the incidence of tibial plateau fractures (Study I) and to report the short-term outcomes in bicondylar tibial plateau fractures treated with a circular external fixator (Studies III and IV). Moreover, the aim was to report the short-term outcome in lateral tibial plateau fractures treated with bone tamp reduction and percutaneous screw fixation (Study II).

2.1.1. AIM OF STUDY I

The aim of the present study was to provide up-to-date information on the incidence and basic epidemiology of tibial plateau fractures in a large, unselected patient population, reporting the trauma mechanisms involved and the distribution of fractures using a validated fracture classification based on CT scans.

2.1.2. AIM OF STUDY II

The aim of the study was to evaluate the patient-reported and radiological outcomes after lateral tibial plateau fractures treated with minimal invasive bone tamp reduction and percutaneous screw fixation.

2.1.3. AIM OF STUDY III

The primary aim of this study was to report the patient-reported quality of life (HRQOL) from surgery to eight weeks after frame removal following a bicondylar tibial plateau fracture[1]. The secondary explorative aim was to analyse variables affecting patient-reported outcomes and time to union.

2.1.4. AIM OF STUDY IV

The primary aim of this study was to report the patient-reported health related quality of life (HRQOL) at 12 months after frame removal following a bicondylar tibial

[1] The aim is rephrased compared to the original article as only a subgroup of patients is included in this thesis. (included: Bicondylar tibial plateau fractures, excluded: shaft and distal tibial fractures)

plateau fracture[2]. The secondary explorative aim was to report the socioeconomic characteristics of the patient group and report the rate of return to work 12 months after frame removal.

2.2. HYPOTHESES

2.2.1. STUDY I

No hypothesis was presented

2.2.2. STUDY II

The hypothesis was that at long-term follow-up, patient-reported and radiological outcomes after lateral tibial plateau fractures treated with minimal invasive bone tamp reduction and percutaneous screw fixation would result in satisfactory outcomes. Secondly, the study hypothesis was that the study population would report worse outcomes compared with an established reference population. Furthermore, the hypothesis was, that age, gender, muscle strength, walking asymmetries, pain and QOL would influence such knee injury-specific outcome measurements such as the Knee Injury and Osteoarthritis Outcome Score (KOOS).

2.2.3. STUDY III

The predefined hypothesis was; that patients would report worse outcome when compared with the Danish reference population on Eq5d-5L index score from time of surgery to eight weeks after frame removal following a bicondylar tibial plateau fracture[3].

[2] The aim is rephrased compared to the original article as only a subgroup of patients is included in this thesis. (included: Bicondylar tibial plateau fractures, excluded: shaft and distal tibial fractures)

[3] The hypothesis is rephrased compared to the original article as only a subgroup of patients is included in this thesis. (included: Bicondylar tibial plateau fractures, excluded: shaft and distal tibial fractures)

2.2.4. STUDY IV

The predefined hypothesis was; that patients would report worse outcome compared with the Danish reference population on Eq5d-5L index score at 12 months after frame removal following a bicondylar tibial plateau fracture[4].

[4] The hypothesis is rewritten compared to the original article as only a subgroup of patients is included in this thesis. (included: Bicondylar tibial plateau fractures, excluded: shaft and distal tibial fractures)

CHAPTER 3. METHODOLOGY

3.1. DESIGN

The four studies in the present PhD thesis included a population-based epidemiological study of patients treated for a tibial plateau fracture, a retrospective cross-sectional study of patients treated for a lateral tibial plateau fracture and two prospective follow-up cohort studies on the treatment of bicondylar tibial fractures.

The two latter studies included patients treated for a complex tibial fracture but only the patients treated for a bicondylar tibial plateau fracture, are included in this thesis.

All studies were conducted in accordance with the ethical standards of the responsible committee and within the ethical principles of the 1975 Declaration of Helsinki. The local ethics committee stated the studies did not need permission to be commenced from the system of research committees. The studies were approved by the Danish Data Protection Agency.

3.2. STUDY POPULATIONS

3.2.1. STUDY I

The study included the population of the North Region of Denmark, which in the 6-year study period from 2005 to 2010, had an average population of 576,364. Aalborg University Hospital (level 1 trauma centre) serve the region with six minor hospitals. All patients in the Region treated for a tibial plateau fracture between 2005 and 2010 were included. The patients were identified from the regional medical record system. A total of 355 patients were identified and included in the study.

3.2.2. STUDY II

All patients treated for a tibial plateau fracture between 2005 and 2010 at Aalborg University Hospital were identified from the medical records system. All patients with AO 41-B1, AO 41-B2 and AO 41-B3 fractures of the lateral tibial plateau treated with percutaneous cannulated screw fixation were included.

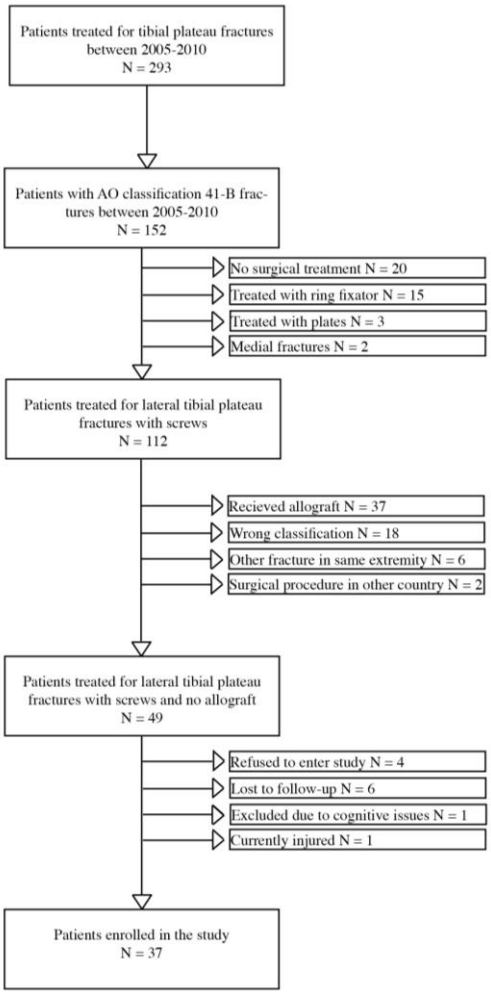

Figure 3-1 Patient flow entering study II

Patients with other plateau fractures, open fractures, fractures treated with open reduction, plates or/and external fixation and fractures requiring graft were excluded.

Patients who were unable to fill out questionnaires because of physical or psychological disabilities were excluded.

A total of 37 patients entered the study. All participants gave written informed consent at the time of examination.

3.2.3. STUDY III

All patients treated with a ring fixator following a complex fracture of the tibia between December 2012 and May 2014 at Aalborg University Hospital were included in the Traume Ilizarov Database (TID). Patients with complex tibia fractures treated without a ring fixator were excluded. Patients who were unable to fill out questionnaires because of physical or mental disability were excluded. Of the 60 patients included in the database two patients were excluded because of cognitive issues and one patient did not want to participate. Of the remaining 57 patients 1 left the country. Of the remaining 56 patients, 29 presented with a bicondylar tibial plateau fracture.

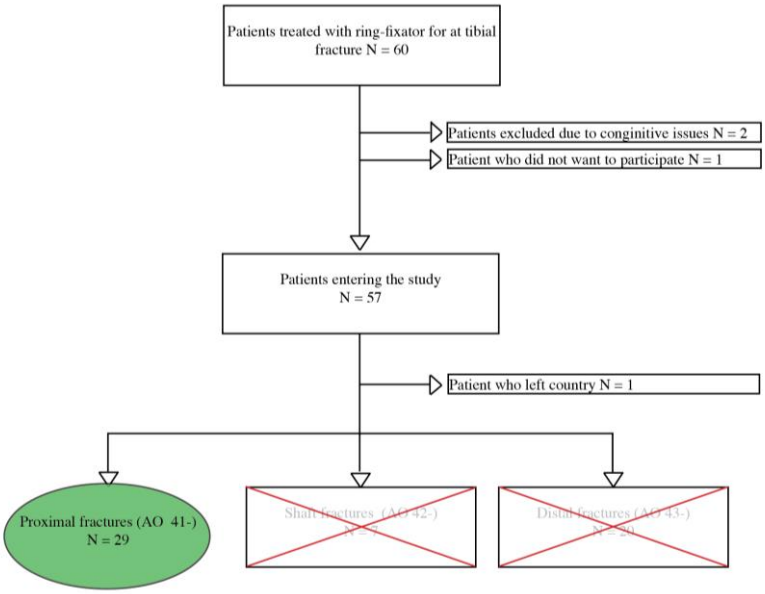

Figure 3-2 Patient flow entering study III

3.2.4. STUDY IV

All patients treated with a ring fixator following a complex fracture of the tibia between December 2012 and May 2014 at Aalborg University Hospital were included in the Traume Ilizarov Database (TID). Patients with complex tibia fractures treated without a ring fixator were excluded. Patients who were unable to fill out questionnaires because of physical or mental disability were excluded. Of the 60 patients included in the database 14 were lost to follow-up. Of the remaining 46 patients, 24 presented with a bicondylar tibial plateau fracture.

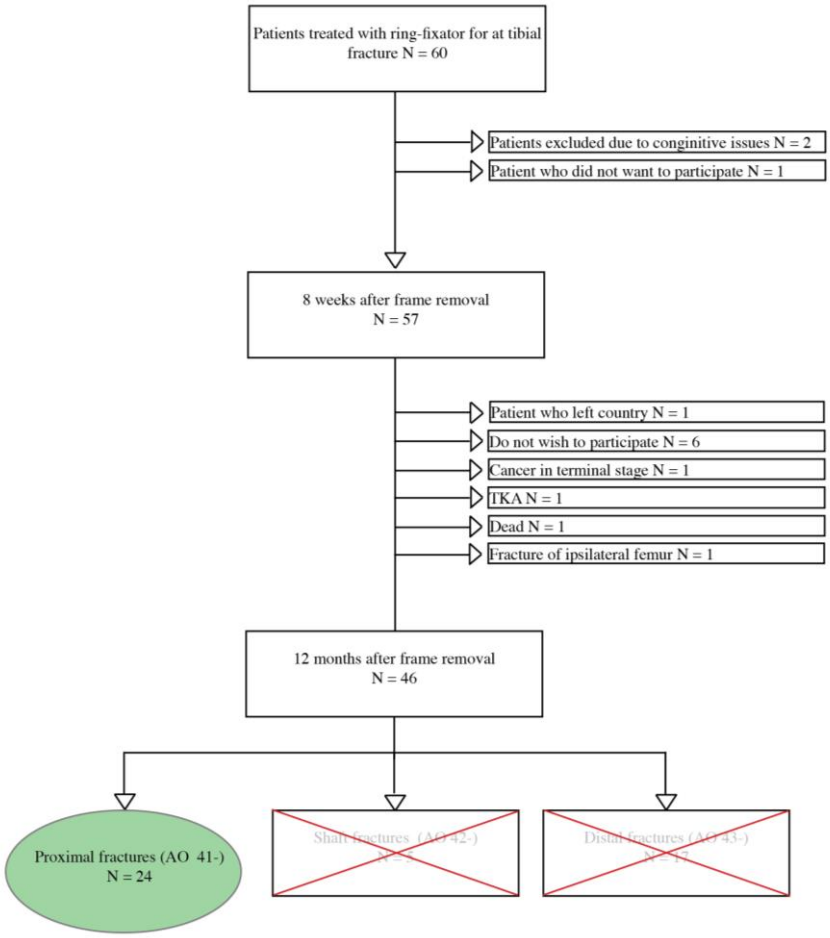

Figure 3-3 Patient flow entering study IV

3.3. OUTCOME MEASUREMENTS

3.3.1. PATIENT-REPORTED OUTCOME – QUESTIONNAIRES

3.3.1.1 EQ-5D-5L

Eq5d-5L is an instrument measuring health related QOL(HRQOL) in population health surveys, clinical trials and economic evaluations[51]. The instrument has been validated in a variety of settings and is increasingly being used in clinical studies[51]. The questionnaire consists of five dimensions, mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension has five levels ranging from no problems to severe problems. The individual Eq5d-5L health status can be expressed by a five digit profile derived from the answers in the five questions. The Danish time-trade-off (TTO) scoring algorithm with crosswalk index values[52] is then used to weight each respondent's profile, resulting in an index value[51].

The Eq5d index can be regarded as a continuous outcome score[51]. A score of 1.00 indicates perfect health, 0.00 indicates a state of health comparable to death and negative values indicate a state worse than death[53]. The Eq5d index range is from -0.59 to 1.00. The minimal detectable clinically relevant difference is reported to be 0.074 Eq5d-5L index points[54]. A reference population from Denmark is available[51].

3.3.1.2 Knee Injury and osteoarthritis Outcome Score (KOOS)

Knee Injury and Osteoarthritis Outcome Score (KOOS)[55], is a standardised and validated instrument used to give a broader picture of clinical status following knee injury and knee osteoarthritis[55]. The questionnaire includes 42 questions with a possible score between zero and four[55]. A total score of zero to 100 is calculated for each of the five subscales[55]. In accordance with the user's guide[55], if the number of missing items is fewer than or equal to two items in a given subscale they are substituted by the average item value for that subscale. If more than two items in a specific subscale are missing, the response are deemed invalid and no subscale score is calculated[55]. A total score of 100 indicates no symptoms and zero indicates major symptoms[55]. KOOS reference data[56] from a general population-based sample in southern Sweden is available. The minimal important clinical change is currently suggested to be eight to ten KOOS points[55].

3.3.1.3 Pain

Pain was assessed with a visual analogue scale (VAS) of 100 mm with "no pain" and "worst pain" as the endpoints. VAS is used as an indicator of the intensity of pain as well as the psychological component of pain and has been used intensively in research on both chronic and acute pain for a wide variety of conditions[45,57]. The score has been validated in a number of studies and the minimal detectable clinical difference has been found to be three[58] .

3.3.1.4 Major Depression Inventory (MDI)

The major depression inventory (MDI) is a validated self-reported mood questionnaire developed by the WHO[59]. The MDI differs from other major self-reported inventories in its ability to generate an ICD-10 and DSM-IV diagnosis of clinical depression in addition to an estimate of symptom severity[59,60]. MDI contains 10 items of which two are divided into sub-items a and b. Each item is measured on a six point likert scale in which the patient states the amount of time the symptoms have been present during the past 14 days[60]. The MDI is scored according to specific guidelines[60]. A score of zero indicates no depression and 50 indicates severe depression[59,60]. The categories no depression, less than 20, mild, 20 to 24, moderate, 25 to 29 and severe depression, 30 or more, are used[59,60].

3.3.2. OBJECTIVE OUTCOME

3.3.2.1 Range of motion

Knee range of motion is assessed by active extension and flexion of the knee with the patient supine on the examination table. The patient is asked to perform maximal flexion and extension and the angle is measured by a goniometer. The intra-tester reliability of the goniometer measurement of knee range of motion is reported to have high ICC values (ICC 0.78-0.99)[61].

3.3.2.2 30 Second chair stand test

The 30 second chair stand test counts the number of times an individual can rise to a full stand from a seated position on a 43cm chair without armrests in a 30 second time period[62]. The test is constructed to measure functional lower extremity muscle strength, which has been associated with the functions of daily activities such as gait, stair climbing and balance[62]. The test is found to have a moderate to high correlation with leg-press performance in both genders, and is found to be a reasonable reliable and valid indicator of lower muscle strength[62,63]. The intra-tester reliability of the test is reported to have high ICC values >0.97[64].

3.3.2.3 Walking symmetry

Walking ability and gait asymmetries are measured while the patient walks along a 6 meter long measuring mat (GaitRITE System®)[65]. The test is performed twice. The mat registers electronic footprints and present gait velocity, cadence as well as temporal and spatial parameters of the gait cycle[65]. The method has been thoroughly described and validated in a number of studies[65,66]. The test-retest reliability of the procedure is reported to have high ICC values (ICC 0.82-0.92)[67].

3.3.3. RADIOLOGICAL OUTCOME

3.3.3.1 AO classification

The AO classification of fractures was first introduced by Müller as a comprehensive classification of fractures of the long bones[16]. The classification was later revised combining the Müller/AO classification and the OTA classification as a single alphanumeric classification based on the location and severity of the fracture[16]. The latest revision was published in 2007[16]. The AO classification system is reported with fair to moderate inter-observer reliability but excellent intra-observer reproducibility[22]. The inter- and intra-observer variability greatly improve when CT scans are used in conjunction with standard x-rays[23].

3.3.3.2 Evaluation of depression and condylar widening

Evaluation of the alignment and depression of the articular surface and condylar widening were performed as described by Rasmussen et al.[4].

3.3.3.3 Kellgren and Lawrence score

The Kellgren and Lawrence (KL) score is an assessment of the radiological severity of osteoarthritis in joints based on X-rays[68]. The score is binomial ranging from 0, which indicates no radiological changes to four which indicates severe osteoarthritis[68]. The inter- and intra-tester reliability of the KL scores in knee is reported to have a high correlation coefficient of 0.83[68].

3.4. PROCEDURES

3.4.1. STUDY I

The main outcome was the incidence of tibial plateau fractures in the period 2005 to 2010.

Retrospective reviews of clinical and radiological records were performed in April 2014. Clinical information about age, gender, trauma mechanism and high- or low-energy trauma was obtained (high-energy trauma was defined as a fall from >3 metres or fracture owed to traffic and road accidents at more than 30 km/h). Information about length of hospital stay, time to theatre following admission, conservative or operative treatment, additional bone injury and multi-trauma was recorded. CT scans were performed on all patients with a suspected or confirmed tibial plateau fracture to classify the fracture and plan operative or conservative treatment. Classification was based on the AO classification[16].

3.4.2. STUDY II

The main outcome measure was the Knee Injury and Osteoarthritis Outcome Score (KOOS)[69].

All patients who met the inclusion criteria received a letter inviting them to participate in the study. All patients were examined in December of 2013. Descriptive characteristics consisted of patient demographics, fracture classification AO[16] and radiological evaluation. Outcome assessment consisted of radiological outcome, functional outcome scores, pain, 30-s chair stand test, walking ability and HRQOL.

3.4.2.1 Operative procedures

Experienced trauma surgeons performed all the procedures. All patients had a Computer Tomographic (CT) scan as part of their preoperative planning. After the drawing of fracture lines and landmarks on the patients, a 3 cm incision was made over the anterior of the tibia. The periosteum was held aside and a canal was drilled with an 11 mm cannulated coring reamer with collar pin guided by fluoroscopy. Through the intramedullary canal the fracture was reduced with bone tamps. The goal was to reduce the joint anatomically, visualised by intraoperative fluoroscopy in multiple planes. Finally, the fracture was fixed with a minimum of two percutaneous 7.3 mm screws introduced from the lateral side. Additional screws were placed as needed. The surgical steps of the procedure are presented in Figure 3.1

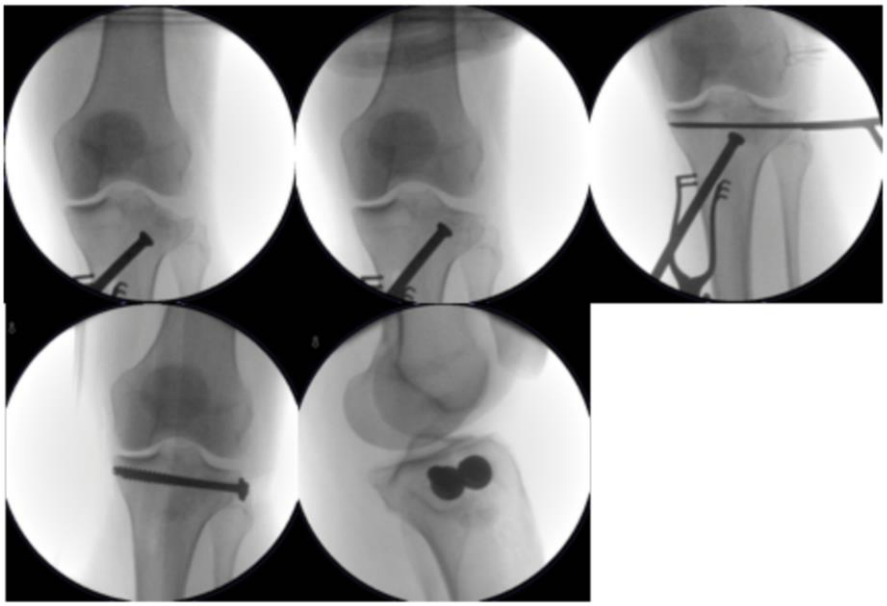

Figure 3-4 Surgical procedure step 1-5.

Patients with split fractures (AO type B1) who did not require bone tamping were treated only with percutaneous screw fixation.

3.4.2.2 Postoperative procedures

All patients were immobilised in an angle stable brace with the ability to control range of motion. All patients started early physiotherapy with a standardised postoperative rehabilitation protocol. Active range of motion was initiated within 24 hours after surgery. Patients were kept non-weight-bearing for six weeks postoperatively. AP- and lateral radiographs were obtained preoperatively and at six weeks postoperatively.

3.4.3. STUDY III

The main outcome measurement was the Eq5d-5L index[70].

Patient baseline characteristics were obtained at the time of admission to hospital. All patients were systematically examined at the outpatient clinic after two weeks, six weeks, three months and six months or until union and removal of the frame. A final examination was conducted eight weeks after removal of the frame.

Information about age, gender, trauma mechanism, type of trauma, fracture classification, co-morbidities and complications was registered. Fracture classification was performed according to the AO classification[16] and was conducted on preoperatively obtained CT scans.

3.4.3.1 Surgical procedures

Bicondylar fractures of the tibial bone entering the study were all treated by an external ring fixator. The surgeons at Aalborg University Hospital, Department of Orthopaedic Surgery preferred to manage proximal tibial fractures with initial screw fixation of joint-bearing bone fragments and, if necessary, with exposure of the joint surface. Both autogeneous and allogeneous bone grafting were used. Metaphyseal-diaphyseal fractures were bridged by one or more rings. The frame was connected to the bone by hydroxyapatite-coated half-pins and K-wires with olives as needed. After applications of the ring fixator alignment was assessed and corrected guided by fluoroscopy. Amendments such as proximal fixation of the femur were made when deemed appropriate.

Figure 3-5 Surgical steps in bicondylar fractures

3.4.3.2 Post operative procedures

All patients were systematically examined at the outpatient clinic every six weeks until fracture union. In general patients with fractures of the joint surfaces were kept non-weight-bearing for six weeks. The decision regarding fracture union and the removal of the frame was as described by Ramos et al.[25] (The fracture was regarded as united when three of four cortices on antero-posterior and lateral X-rays showed bridging callus, the fracture was stable under manual stress and the patients were able to walk without pain after the connection rods had been removed)amo.

All patients received a standardised physiotherapy programme from the first day following surgery and daily until discharge. Following discharge, the patients were managed in the outpatient clinic. The rehabilitation programme has a special focus on knee and ankle range of motion, muscle function and the ability to maintain these functions in conjunction with management of functions of daily living. In general

patients were seen in the physiotherapy outpatient clinic one to three times a week for three to five months.

3.4.3.3 Radiological procedures

Radiographic examinations including X-rays and preoperative CT scans were obtained for all patients. Postoperatively, X-rays of the entire low leg were obtained and used to evaluate the quality of reduction and to adjust alignment. Radiological examination was performed at six weeks, three months and every six weeks until union. At the final examination eight weeks after frame removal, radiological assessments were made on AP and side X-rays. Fractures were evaluated concerning alignment and depression of the articular surface and condylar widening as described by Rasmussen et al.[4]. Signs of osteoarthritis were evaluated as described by Kellgren and Lawrence[68].

3.4.3.4 Patient-reported procedures

All patients filled in the Eq5d-5L, KOOS, pain and MDI questionnaires at two weeks following surgery and at every out-patient clinical visit until the eight weeks after fracture union and removal of the frame.

3.4.4. STUDY IV

The primary outcome measurement was the Eq5d-5L index[70].

This study contains the same study population and procedures as study III, regarding surgical procedures, radiological procedures and patient-reported outcomes with the addition of another data point 12 months following fracture union. At 12 months after fracture union all patients filled in the Eq5d-5L, KOOS, pain and MDI questionnaires. Information concerning employment status was obtained at time of admission and at follow-up. X-rays were obtained and evaluated regarding depression and alignment as described by Rasmussen et al.[4]. Signs of osteoarthrosis[68] were evaluated as described by Kellgren and Lawrence [68].

3.5. STATISTICS

3.5.1. STUDY I

Mean values and SDs were given for continuous variables. Frequencies and percentages were used for categorical data. Normal distribution was checked visually by QQ plots. Statistical analysis was performed with SPSS software (PAWStatistic, version 21.0; IBM Corporation, Armonk, New York).

3.5.2. STUDY II

The sample size was limited by the number of patients entering the study.

Mean values, SD or range were given for continuous variables. Frequencies were used for categorical data. Normal distribution was checked visually by QQ-plots and 95% CI were used for comparison with reference populations. Paired t-test was used to compare gait parameters. A p value <0.05 was assumed significant. The statistical analysis was performed by SPSS (PAWStatistic 21.0).

3.5.3. STUDY III

A sample size was based on the hypothesis that patients would experience a worse Eq5d-5L index score eight weeks after union and frame removal compared with the Danish reference population[51]. A power calculation was performed on the basis of a calculated mean and SD from a comparable study by Ramos et al.[25] with a SD of 0.18 and mean of 0.80 (power 80% and a significance level of 5%) was used. The power calculation suggested 19 patients were needed. To account for drop-out in the study period, a limit of no fewer than 25 patients were established.

The distribution of variables was checked visually for normality by QQ-plots. Continuous data were expressed as mean and SD or range. Categorical data were expressed as frequencies. A P-value of < 0.05 was taken to indicate significance. 95% CI was used to compare the study population to the reference populations. The statistical analysis was performed by Stata (version 13).

3.5.4. STUDY IV

Study 4 use the same statistical methods as study III.

CHAPTER 4. SUMMARY OF RESULTS

4.1. STUDY I

A total of 355 patients was treated for a tibial plateau fracture between 2005 and 2010. The demographics and baseline characteristics are presented in table 4-1.

Characteristics of the 355 patients	
Patients, N male/female	166/189
Age, years mean (SD)	52.6 (18.3)
Age years, women mean (SD)	57.7 (18.3)
Age years, men mean (SD)	46.8 (16.4)
Side of fracture (right/left)	43% / 57%
Treatment (cast/surgery)	7.9% / 92.1%

Figure 4-1Baseline characteristics study I

The average incidence of tibial plateau fracture was 10.3/100,000/year. The incidence was 9.6/100,000/year in men and 11.0/100,000/year in women. The distribution among age groups and gender is presented in Figure 4.2.

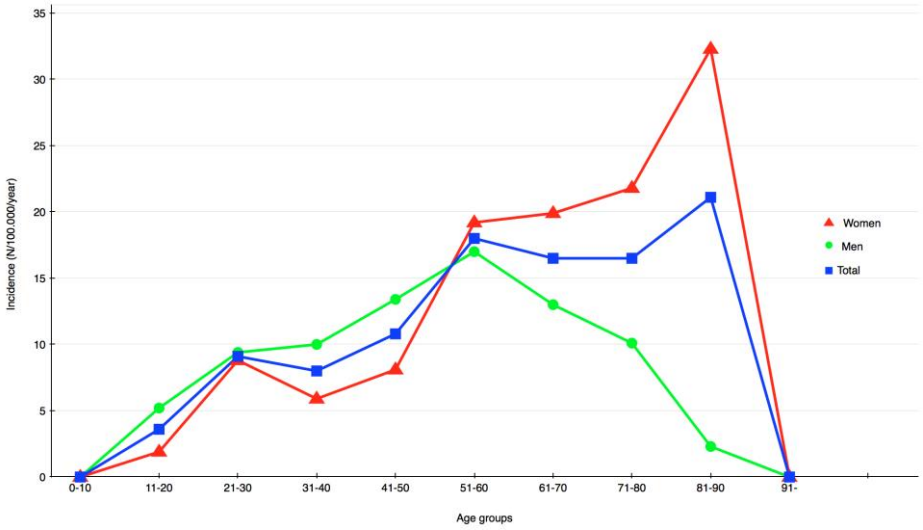

Figure 4-2 Incidence of tibial plateau fracture divided into age groups and gender.

The AO-classification of fractures is presented in table 4-3. AO-type 41-B3 was the most common fracture type, representing 35% of all tibial plateau fractures, followed by AO-type 41-C3 fracture, representing 18% of all fractures.

Table 2: AO classification, 41-

AO type	N	%
A1	4	1,1%
A2	22	6,2%
A3	4	1,1%
B1	30	8,5%
B2	59	16,6%
B3	123	34,6%
C1	28	7,9%
C2	23	6,5%
C3	62	17,5%
	355	100,0%

Figure 4-3AO classification of fractures.

The distribution according to AO classification and mechanism of injury showed a weak tendency toward AO type 41-C fractures in the high-energy trauma group and towards AO type 41-B fractures in the low-energy trauma group. Men had an increased frequency of injuries as a result of motorcycle or other motorised vehicle accidents and also as a result of falls from a height. Women had an increase in injuries as a result of bicycling, walking, indoor activity, and falls from a height, with a tendency toward AO type B2 and AO type B3 fractures. Table 4-4.

Table 3

Mechanism of Injury and Fracture Classification

	No.									
AO Type[a]	High Energy[b]	Low Energy[b]	Multiple Traumatic Injuries	Car	Motorcycle	Other Motorized Vehicle	Bicycle	Walking	Indoor	Fall From Height
41-A1	2	1	0	0	0	1	0	1	0	1
41-A2	8	14	3	1	0	5	0	3	11	2
41-A3	4	0	1	1	0	0	0	0	0	2
41-B1	14	14	3	3	1	2	4	9	8	3
41-B2	19	39	2	3	0	6	3	20	10	16
41-B3	49	74	16	8	7	9	20	29	15	34
41-C1	15	13	6	2	1	4	5	8	7	1
41-C2	15	8	7	0	3	7	2	6	5	0
41-C3	41	20	4	3	3	14	8	10	11	12
Total	167	183	42	21	15	48	42	86	67	71
Total women	64 (38%)	123 (67%)	10 (24%)	7 (33%)	2 (13%)	7 (15%)	30 (71%)	56 (65%)	54 (81%)	32 (45%)
Total men	103 (62%)	60 (33%)	32 (76%)	14 (67%)	13 (87%)	41 (85%)	12 (29%)	30 (35%)	13 (19%)	39 (55%)

[a]*Information on 5 patients not included because of missing data in the medical charts.*
[b]*Information on 3 patients not included because of missing data in the medical charts.*

Figure 4-4 Mechanism of injury

The annual incidence between 2005 and 2010 show a large deviation throughout the years, ranging from 7/100,000/year to 13/100,000/year. See Figure 4-5.

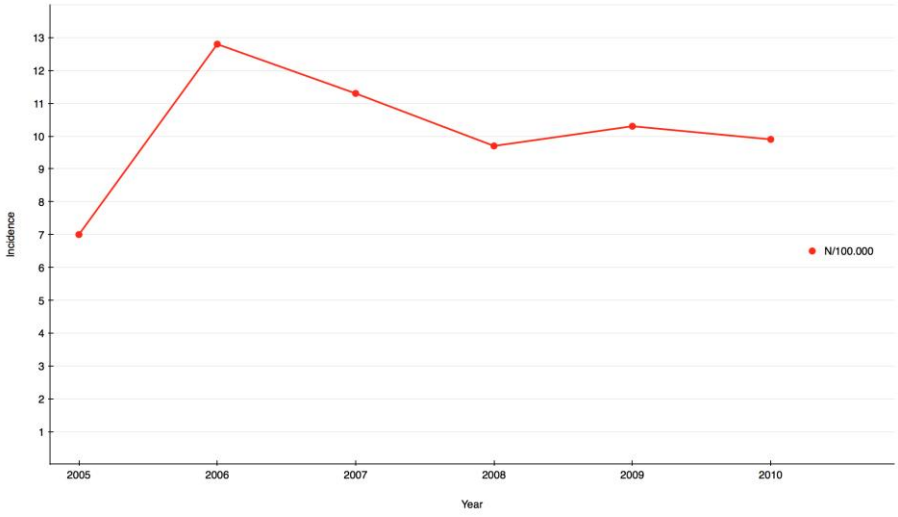

Figure 4-5 Yearly incidence of tibial plateau fractures between 2005 and 2010

4.2. STUDY II

A total of 37 patients participated in the study. The mean follow-up time was 5.2 years with a range from two to eight years.

The baseline variables from all patients are presented in Table 4-6.

Baseline characteristics of the 37 patients	
Patients, N male/female	17/20
Age follow-up, years mean (SD)	50.9(14.4)
Age surgery, years mean (SD)	45.1(14.4)
Follow-up time mean (SD)	5.2(1.5)
Müller AO-classification	
41-B1	3
41-B2	5
41-B3	29
Trauma N, high energy/low energy trauma	8/29
Complications, N	
Nerve injury at time of injury	1
Nerve injury during surgery	1
Secondary surgery, N	13
Removal of screws before follow-up,	13
Total Knee Replacement	2
Arthroscopy	4

Figure 4-6 Baseline characteristics study II

4.2.1. PATIENT-REPORTED OUTCOMES

Compared with the established reference population[56], the study population showed a lower (worse) KOOS outcome, but the only significant different KOOS score was for the subgroup Sport (Table 4-7).

		KOOS				
		Pain	ADL	SYMP	QOL	SPORT
Study population	Mean	84.4	88.4	80.7	70.3	59.6
	95% CI	78.3 - 90.5	83.3 - 93.5	74.1 - 87.3	61.6 – 79.0	47.6 – 71.6*
Reference population	95% CI	86.7 - 88.2	86.5 - 88.1	85.4 - 86.9	77.4 - 79.6	72.5 - 75.1

		Eq5d-5l	
		Index	VAS
Study population	Mean	0.815	78
	95% CI	0.755 - 0.874	72 – 84
Reference population (Male/Female 50-59 years)	Mean	0.888/0.858	
	95% CI	0.880 - 0.896 / 0.850 - 0.866	

Figure 4-7 KOOS and Eq5d-5L scores compared to reference populations

The mean Eq5d-5L index score was 0.815 (CI: 0.755-0.874). The mean Eq5d-5L VAS was 78.0 (CI:72-84). Compared with the established reference population from Denmark [34], the study population showed a tendency towards a worse Eq5d-5L index, but it was not significant (Table 4-5).

4.2.2. RADIOLOGICAL OUTCOME

At final follow-up 5.2 years after surgery, 34 of 37 patients had maintained anatomical reduction evaluated on weight-bearing AP and side X-rays. Two patients had received total knee replacement (TKR) and one patient had a depression of 6 mm on side X-ray. The two patients who received TKR had subsided more than 5 mm at the six-week follow-up.
At baseline, 34 patients were classified according to Kellgren–Lawrence[68] type 0, two patients were classified as type 1 and one patient as type 2. At follow-up 12 patients were classified as type 0, 15 patients with type 1 and eight patients with type 2.

4.2.3. FUNCTIONAL OUTCOME

The mean knee flexion was 125.7°, range 95°–135°. Thirty-four patients achieved a

knee extension of 0°, two patients experienced a knee extension lag of 5° and one patient had a knee extension lag of 10°.

The mean outcome for the 30-s chair stand test was 13.5, range 8–25.

No significant difference in the GaitRITE-measurements between the injured and the non-injured leg was observed for any of the measured gait parameters ($p > 0.08$).

4.2.4. PAIN

The VAS score for pain during activity was reported with a range of zero to eight. Twenty-nine patients reported no pain, six patients reported VAS between one and five and two patients reported VAS between seven and eight. The VAS score for rest pain was reported with a range of 0–4. Thirty-three patients reported no pain and four patients reported VAS between one and four.

4.3. STUDY III

Twenty-nine patients in the study presented with a tibial plateau fracture. Demographics and baseline characteristics are presented in Table 4-8.

Baseline characteristics of the 29 patients	
Age at time of fracture, mean (range)	57.7(32-82)
Gender Male/Female	14/15
Smoker Yes/No	16/13
Side of injury, Right/Left/Bilateral	13/15/1
High-/low-energy trauma	9/20
Co-morbidities	
ASA-score, mean(SD)	1.7(0.7)
Charlston co-mobidity score, mean(SD)	2.8(1.8)
Open/closed fracture	3/26
Multi-trauma Yes/No	6/ 23

Figure 4-8 Baseline characteristics study III

4.3.1. PATIENT-REPORTED OUTCOMES

The mean Eq5d-5L index from surgery to union is presented in figure 4-9.

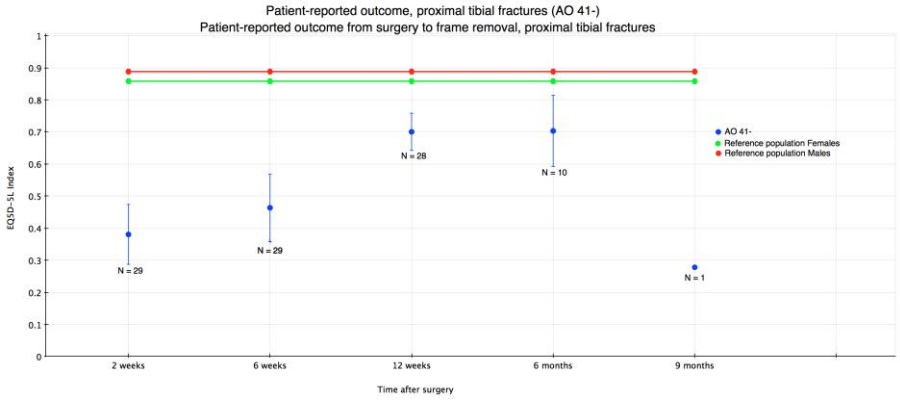

Figure 4-9 Mean Eq5d-5L and 95 % CI compared to reference population

Eight weeks after frame removal the mean Eq5d-5L index was 0.695 (CI: 0.627–0.763). The mean Eq5d-5L VAS was 74.5 (CI: 65.2–83.9). Compared with the

established reference population from Denmark[51], the study population showed a significantly worse Eq5d-5L index throughout the observational period. (Table 4-7)

Eight weeks after frame removal the mean KOOS score was pain 65.6 (CI: 56.1–75.2), symptoms 54.5 (CI: 44.3–64.6), ADL 69.8 (CI: 58.6–81.0), sport 28.6 (CI: 17.3–39.8) and QOL 48.0 (CI: 38.1–57.8). Compared with the established reference population[56], the study population showed a significantly worse KOOS outcome for all five subgroups. (Table 4-10)

		KOOS				
		Pain	ADL	SYMP	QOL	SPORT
Study population	Mean	65.6	69.8	54.5	48.0	28.6
	95% CI	56.1 - 75.2	58.6 - 81.0	44.3 - 64.6	38.1 - 57.8	17.3 - 39.8
Reference population	95% CI	86.7 - 88.2	86.5 - 88.1	85.4 - 86.9	77.4 - 79.6	72.5 - 75.1

		Eq5d-5l	
		Index	VAS
Study population	Mean	0.695	74.5
	95% CI	0.627 - 0.763*	65.2 - 83.9
Reference population (Male/Female 50-59 years)	Mean	0.888/0.858	
	95% CI	0.880 - 0.896 / 0.850 - 0.866	

Figure 4-10 KOOS and Eq5d-5L scores compared with reference populations

4.3.2. FUNCTIONAL OUTCOMES

All fractures united during the study period. The ring fixator was removed at an average of 23.5 weeks (range 9 to 45). At the final examination eight weeks after frame removal, nine patients were out of alignment or had an articular depression of more than 3 mm.

At the final examination eight weeks after frame removal the mean knee flexion was 116.9° (CI: 112.1–121.7). Twelve patients experienced a knee extension limitation of 5° or less and two patients had a knee extension limitation exceeding 10°.

4.3.3. PAIN

The VAS score for rest pain 8 weeks after frame removal was reported with a range from 0 to 6. Twenty-two patients reported no pain, five patients reported VAS between 1 and 5 and two patients reported VAS 6.

4.3.4. MENTAL HEALTH

Overall, 21% (6 out of 29) of patients reported mild to severe depression eight weeks after frame removal evaluated using MDI scores. Three patients reported an MDI scores between 20 and 30 indicating mild to moderate depression, and three patients had a score of > 30 indicating severe depression.

4.4. STUDY IV

Twenty-four patients in the study presented with a tibial plateau fracture. Demographics and baseline characteristics are presented in Table 4-11.

Baseline characteristics of the 24 patients	
Follow-up time from injury, months (SD)	18.6(3.2)
Follow-up time from frame removal, months(SD)	12.3(3.5)
Age at time of fracture, mean (range)	58.5(39-82)
Gender Male/Female	11/13
Smoker Yes/No	11/13
Side of injury, Right/Left/Bilateral	11/12/1
High-/low-energy trauma	8/16
Co-morbidities	
ASA-score, mean(SD)	1.6(0.7)
Charlston co-mobidity score, mean(SD)	2.8(1.7)
Open/closed fracture	1/23
Multi-trauma Yes/No	5/19

Figure 4-11 Baseline characteristics of study IV

4.4.1. PATIENT-REPORTED OUTCOMES

Twelve months after frame removal, the mean Eq5d-5L index score was 0.715(CI: 0.635–0.795). The mean Eq5d-5L VAS was 76 (CI: 68–84). Compared with the established reference population from Denmark[51], the study population showed a significantly worse Eq5d-5L index 12 month after union.

Twelve months after frame removal, the mean KOOS scores were pain, 69 (CI: 59–79): symptoms 65 (CI: 54–75): ADL 71 (CI: 62–81): sport 30 (CI: 19–42) and QOL 52 (CI: 39–65). Compared with the established reference population[56], the study population showed a significantly worse KOOS outcome for all five subgroups.

4.4.2. RADIOLOGICAL OUTCOMES

Five of the 24 patients presented with either malalignment, condylar widening >5 mm and/or articular depression of more than 5 mm 12 months after union. The radiological outcomes of osteoarthritis of the knee (Kellgren and Lawrence[68]) showed

three patients with no or doubtful signs of osteoarthritis (Type 0 and 1), 13 patients with minimal signs of osteoarthritis (Type 2) and six patients with moderate signs of osteoarthritis (Type 3). One patient with Type 3 osteoarthritis was treated with a total knee replacement (TKR) during the study period.

4.4.3. PAIN

The VAS score for resting pain was reported as a range from zero to six cm. Sixteen patients reported no pain at rest, five patients reported a VAS between one and three and three patient-reported a VAS scores between four and six.

4.4.4. SOCIOECONOMIC OUTCOMES

The distribution of social classes showed one patient in group I, two patients in group III, 13 patients in group IV and eight patients in group V. The majority (88%) of patients were grouped into social classes IV and V, indicating a high degree of social deprivation in the study population.

Of the 24 patients in the study population 16 patients were below the age of 65 at the time of follow-up, which was the official retirement age in Denmark. Of the 16 patients below the age of 65, eight patients were employed prior to injury and one patient above the age of 65 years was employed. Of the nine patients who were employed prior to the injury, two patients returned to pre-injury work, two patients were employed on reduced working hours and five patients were unable to return to work 12 months after union and frame removal. Of the five patients unable to return to work, none was eligible to receive early retirement. The patient above the age of 65 returned to employment.

CHAPTER 5. DISCUSSION

5.1. MAIN FINDINGS

The aim of the present PhD thesis was to report the incidence of tibial plateau fractures (Study I) and to report the short-term outcomes in bicondylar tibial plateau fractures treated with a circular external fixator (Studies III and IV). Moreover, the aim was to report the short-term outcomes in lateral tibial plateau fractures treated with bone tamp reduction and percutaneous screw fixation (Study II).

Study I reported an incidence of 10.3/100,000/year from a complete and unselected cohort in the period from 2005 to 2010.

Study II showed that patients with lateral tibial plateau fractures treated with bone tamp reduction and percutaneous screw fixation at a mean of 5.2 years follow-up showed significant difference in one of five KOOS subscales (Sport) compared to a reference population. Furthermore, satisfactory radiological outcomes were observed. At a mean of 5.2 years follow-up two patients had received a TKR because of loss of reduction. All other patients demonstrated no of minimal signs of osteoarthritis.

Studies III and IV suggested that management of bicondylar tibial plateau fractures are challenging and that the patient-reported outcomes are significantly worse compared with reference populations both at eight weeks after union and at an average of 19 months following fracture. Furthermore, study III showed satisfactory maintained radiological reduction and alignment. Study IV showed early onset of post-traumatic knee osteoarthritis of the knee in six (25%) of patients. At follow-up four (44%) of patients had returned to employment.

5.2. INCIDENCE

To the authors knowledge this was the first study to show the incidence of tibial plateau fractures and fracture distribution according to the AO classification based on CT scans and mechanism of injury in a large and well-defined cohort including all age groups.

In 2000, Court-Brown and Caesar[10] concluded that the incidence of fractures is changing quickly as a result of changes in mechanism of injury and ageing of the population. This thesis showed an incidence of tibial plateau fractures in the North

Denmark Region of 10.3 per 100,000 annually between 2005 and 2010. This was lower than the incidence of 13.3 per 100,000 annually in 2000 reported by Court-Brown and Caesar[10] in the United Kingdom. The reason for this difference may be inaccuracy in estimated population size, exclusion of children younger than 12 years, the use of different time periods, and regional differences in the study by Court-Brown and Caesar[10]. Furthermore, this thesis used a six-year study period and found considerable year-to-year variation (7/100,000/year to 13/100,000/year) in incidence between 2005 and 2010, with no obvious tendency. In contrast, Donaldson et al[11] reported an average incidence of 26 per 100,000 annually for the three years surrounding the 1981 census. This seemingly large difference in average incidence may be the result of inclusion of all fractures of the upper end of the tibia and fibula[11]. In contrast, the current thesis included only tibial plateau fractures. Furthermore, Donaldson et al.[11] used an approximated population size to calculate incidence, which is in contrast to the present thesis, which has a known population size.

Most studies of tibial plateau fractures lack accurate information on population size[10,11,14]. In the current study, incidence was based on an unselected and well-defined population. Denmark is one of few countries with a CPR registry and a national patient register (DNPR), which enables researchers to perform more accurate epidemiological research[71].

Based on CT scans, the most common fracture type was AO type 41-B3, representing 35% of all tibial plateau fractures, followed by AO type 41-C3, representing 18% of all tibial plateau fractures. These findings were similar to those of Albuquerque et al.[14] from a comparable time period, although they included only surgically treated fractures at a single trauma centre. Furthermore, CT scans were not used in the classification of fractures. This thesis showed that AO type 41-B fractures were primarily present in women and that AO type 41-C fractures were primarily present in men. In contrast Albuquerque et al[14] did not discuss the sex-specific distribution of fractures in their study, but calculations based on their tables showed that AO type 41-B and AO type 41-C fractures were both more common in men (AO type 41-B, 69%; AO type 41-C, 73%) than in women. This difference might be due to a younger population and an high number of high-energy trauma in the study by Albuquerque et al.[14] compared with the this thesis. Furthermore, the study by Albuquerque et al.[14] was conducted in South America, which may reduce the comparability to Denmark.

Given the change in demography as a result of an aging population[10] a change in the pattern of fractures can be expected[15]. The high incidence of tibial plateau fractures in elderly women, which have been claimed to be of an osteoporotic nature[15], will probably change our understanding of these fractures. Furthermore, Ali et al.[72] concluded that the standard surgical procedure (ORIF) in a mixed group of uni- and bicondylar fractures were insufficient when treating patients with osteoporosis, resulting in a 100% loss of reduction. The implications of this shift in incidence towards an increase in osteoporotic fractures of the tibial plateau, might imply a shift

towards different fixation methods or different grafting materials in the elderly osteoporotic patients[72], but more research is needed.

5.3. PATIENT-REPORTED OUTCOMES

A small number of studies have reported on patient-reported outcome measurements following a **lateral tibial plateau fractures**[25,28,45]. In general, there is a lack of studies reporting on both knee injury-specific and general HRQOL following lateral tibial plateau fractures and to the authors knowledge only a single study included an established reference population[45]. The present thesis suggests that patients with lateral tibial plateau fractures have a tendency towards worse knee injury-specific (KOOS) and HRQOL (Eq5d-5L) scores compared with reference populations[51,56], at 5.2 years follow up.

These results are supported by a previous retrospective follow-up study by Elsoe et al. [45] on lateral tibial plateau fractures, treated with bone tamp reduction and allograft showing a significant difference in three of five KOOS subgroups but no significant difference in Eq5d-5L compared with reference populations. However, the present thesis only showed significant difference in one of five subscales on KOOS and no difference in Eq5d-5L compared with reference populations[51,56] following a lateral tibial plateau fracture. These small differences may be the result of relatively small patient groups in both studies resulting in wide confidence intervals, and a difference in the follow-up period between the studies of 2.7 years. Furthermore, Ramos et al.[25] reported comparable Eq5d-5L scores, treating unicondylar tibial plateau fractures by ring fixator with a one-year follow-up, but did not include a reference population in the evaluation. Ramos et al.[25] noted that despite successful treatment of these fractures the lowest scores were found in the KOOS sub-scores Sport and QOL, which is in line with the present thesis. This indicates that the subscale Sport and QOL are the most sensitive in capturing disability following a lateral tibial plateau fracture, and that patients with a high level of physical activity are most limited. In contrast a study by Parkkinen et al.[48] on AO 41-B3 lateral tibial plateau fractures at a mean of 54 months follow-up, reporting on the WOMAC score, found no difference compared to population based normative values, even though this study reported a 40% loss of reduction and 18% malalignment at follow-up.

A number of studies have evaluated the patient-reported outcomes following **bicondylar tibial plateau fractures** including both a knee injury-specific and a HRQOL questionnaire[17,33,46,73]. However, only a small number of studies reporting on patient-reported outcome use reference populations or pre-injured values in comparison[17,33,46].

Studies III and IV reported on the knee injury-specific and HRQOL throughout the treatment period in patients with bicondylar tibial plateau fractures and showed

significantly worse KOOS and Eq5d-5L scores compared with the established reference populations. Studies reporting on patient-reported outcomes following bicondylar tibial plateau fractures support the persistence of limitations in QOL and that many patients do not reach pre-injured levels of QOL [17,25].

A recent prospective study on bicondylar fractures by The Canadian Orthopaedic Trauma Society[17] including both general and knee injury-specific outcome measurements indicated that patient-reported outcomes are more sensitive to residual disability than radiological outcomes at two year follow-up. This indicate the need for patient-reported outcomes in the evaluation of treatment. However, the Canadian study[17] did not compare the patient-reported outcomes with an established reference population, which implies that comparison to the background population is limited. Moreover, Ahearn et al.[33] found generally poor patient-reported outcome measurements despite adequate treatment at a minimum of one year follow-up. In contrast Ramos et al.[25] reported acceptable results on KOOS and Eq5d-5L with the KOOS scores comparable to that of patients following an ACL reconstruction at year after surgery.

In general, the understanding of development in patient-reported HRQOL following a fracture of the tibial plateau is contradictory. The literature lacks large scale prospective studies with long-term follow-up including both knee injury-specific and HRQOL outcomes, to fully understand the development in patient-reported outcomes. This is especially important as the development of disability from these fractures, may have a late onset[44]. Furthermore, the use of both a generic and knee injury-specific questionnaire may be important as knee injury-specific questionnaires have been reported to be more sensitive in capturing knee disabilities compared to HRQOL questionnaires[57]. Furthermore, the literature lacks studies validating questionnaires on tibial plateau fractures, which is important in comparing different treatment strategies.

The literature tends to report on both unicondylar and bicondylar fractures in mixed groups[25,28,46], which could make the ability to distinguish between potentially vast differences between unicondylar and bicondylar fractures difficult. Results from this thesis suggested that such a difference in patient-reported outcomes, both HRQOL and knee injury-specific, are present between the lateral and bicondylar tibial plateau fractures, with a clear tendency toward better outcomes in the lateral tibial plateau fractures when evaluating the outcome following treatment.

5.4. RADIOLOGICAL OUTCOMES

Based on the radiological findings, the present thesis finds that minimal invasive bone tamp reduction and percutaneous screw fixation following a **lateral tibial plateau fracture** showed satisfactory radiological outcomes. Thirty-five out of 37 patients with a lateral tibial plateau fracture had maintained anatomical reduction on X-rays at six-weeks after surgery. At the final follow-up, which was at a mean of 5.2 years postoperatively, 34 patients had still maintained anatomical reduction. The two patients who did not achieve anatomical reduction at the six-week follow-up received a TKR. These findings are supported by Koval et al.[32], with a mean follow-up of 16.2 months, reporting 72.2 % anatomically reduced fractures postoperatively and no further loss of reduction was reported at follow-up. In support, Manidakis et al.[30] reported excellent maintained reduction at an average of 20 months follow-up. In contrast Parkkinen et al.[48] reported a 40% loss of reduction of 3 mm or more at a mean of 54 months following surgery of lateral tibial plateau fractures, treated with plates. This may partly be because of the inclusion of only 41-B3 fractures (split and depression), compared to all surgically treated laterale tibial condylale fractures in the previous studies.

The development of knee osteoarthritis following a lateral tibial plateau fracture has been the focus of several studies[4,30,43,74]. Most patients with maintained reduction in this thesis (97%) showed little or no signs of osteoarthritis at 5.2 years follow-up, based on the Kellgren and Lawrence classification[68]. These findings were supported by Manidakis et al. [30] who reported an overall 15% incidence of knee osteoarthritis in the short-term in patients treated for lateral tibial plateau fractures. In contrast Parkkinen et al.[48] reported an increased risk of 44% of severe secondary osteoarthritis in patients with more than 2mm of maintained depression in AO 41-B3 lateral tibial plateau fractures. This is supported by Manidarkis et al reporting a 78% incidence of osteoarthritis in patients with loss of reduction at follow-up in a mixed group of plateau fractures, indicating a difference in onset of knee osteoarthirits between lateral and bicondylar tibial plateau fractures. A number of studies on mixed tibial condyle fractures have shown late onset of radiological knee osteoarthirits with incidences reported between 17% and 42 % [4,49,74,75], but without distinguishing between laterale and bicondylar fractures.

Compared with lateral tibial plateau fractures, the **bicondylar fractures** in the present thesis had an increased frequency of loss of articular reduction and malalignment, indicating the more severe nature of these fracture types. At a mean follow-up of 19 months, five of the 24 patients presented with either malalignment or articular depression. The level of joint congruity and alignment achieved for bicondylar fractures in the present thesis is comparable to other studies[33,76]. Ahern et al.[33] reported a 15% loss of reduction or angulation at a minimum of one-year follow-up. Krupp et al.[77] reported a 29% loss of reduction at 10 months' follow-up.

Moreover, Ramos et al.[25] reporting 20% of patients with loss of reduction or malalignment from a mixed patient group with tibial plateau fractures, which is in line with this thesis.

Martin et al.[78] assessed the inter-observer variance in the measurement of articular incongruity of 56 tibial plateau fractures, of which 38 had a CT scan available. The study showed that the 95% tolerance limits were ± 12 mm for measurement of maximum articular depression and ±9 mm for the measurements of maximum condylar widening. This indicates that assessment of incongruity may be limited, even when utilising CT scans, maybe partly due to metal artefacts.

The onset of post-traumatic knee osteoarthritis following bicondylar fractures of the tibia has been the subject of a number of studies[4,30,43,74]. In this thesis 25% of patients with bicondylar fractures experienced moderate osteoarthritis, based on Kellgren and Lawrence classification[68]. The incidence of knee osteoarthritis following bicondylar fractures has been reported between 17% and 83% with a wide range in the severity of osteoarthritis[28,49] and with an increasing incidence with patients age at the time of injury[79,80].

The association between loss of reduction and the development of osteoarthritis has been a topic of the literature[80,81,48]. Unfortunately, the present thesis do not report on the correlation between loss of reduction and the development of osteoarthritis due to the small number of patients included. Honkonen et al.[81] noted that articular irregularities correlated poorly with the degenerative process. In constrast, Rasmussen et al.[4] reported that malalignment was significant in the development of posttraumatic osteoarthritis, which is supported by other studies[17,25,48,82]. However, the development of degenerative changes is dependent on a number of factors, and an evaluation of outcome based solely on radiological outcomes is insufficient[80].

In this thesis two patients received a TKR following a lateral plateau fracture at 5.2 years follow-up and one patient had received a TKR following a bicondylar fracture at 19 months follow-up. Wasserstein et al.[44] reported a five times increase in the likelihood of receiving a TKR compared with a matched group from the general population following a tibial plateau fracture.

When receiving a TKR following a fracture, worse outcomes and increased complication rates has been reproted[43]. Scott et al.[43], reported on 31 patients with prior tibial plateau fractures compared to an age and gender matched cohort receiving a TKR because of primary osteoarthritis. They reported an increased complication rate of 13% in the fracture group compared to 1% in the primary osteoarthritis group, but no difference in mean patient-reported oxford knee score between the two groups following surgery. This might indicate that TKR is a viable salvage procedure following a tibial plateau fracture, although an increased risk of complications should be expected.

In general, the association between radiological outcomes and patient-reported outcomes have been reported with week correlations in some studies[17,46], and more research is needed to understand the radiological factors influencing the development in functional and patient-reported outcomes.

5.5. SOFT TISSUE INJURIES

The incidence and importance of soft tissue injuries in combination with tibial plateau fractures have been addressed in a number of studies[17,83,84]. A study by Garner et al.[85] reported that only 1% of surgically treated tibial plateau fractures were completely without soft tissue damage and 91% of patients had signs of lateral and 44% had signs of medial meniscus damage. Furthermore, 68% of patients had signs of some form of injury to the structures of the posterolateral corner of the knee[85]. Bennett el al.[83] studied the incidence of soft tissue injuries related to meniscus, collateral and cruciate ligaments, vessels and nerves and reported that 56% of patients were affected. The most common injuries were medial collateral ligament and menisci injuries, each representing 20% of all patients admitted with a tibial plateau fracture.

Mattiassich et al. [84] evaluated the MRI changes in soft tissues 13 to 31 years following a tibial plateau fracture and reported that 100% of patients exhibited one or more abnormalities. However, in general the patients demonstrated an overall satisfactory condition (WORMS score) of the knee joint, but a high incidence of pathological changes in the menisci and ligaments were observed. The observed radiological abnormalities demonstrated a weak correlation (r=-0.39) with the KOOS score. However, the association between soft tissue injuries and patient-reported outcome lacks evidence.

Unfortunately, data from the present thesis do not include information regarding soft tissue injuries, as MRI is not utilised in all of the patients. A number of authors have argued for the repair of certain soft tissue injuries during initial surgery[17]. However other studies did not find significant difference in outcome between ARIF and ORIF methods[27]. The literature is inconsistent and more research is needed.

5.6. GRAFTING

A number of studies has been conducted on the use of different types of grafting, ranging from autograft to allograft and artificial bone and cement[86–88]. The state of the art was previously iliac crest bone grafting[89] but considerable morbidity has been reported regarding the doner site with the major disadvantages being pain, infection and the possibility of nerve injury[89]. Small variations in the subsidence have been reported between the different grafting materials[86]. To the authors knowledge no consensus regarding the use of a specific grafting material has been established[89], and

most studies have shown only small differences in subsidence, without any consistency in reported effect on functional or patient-reported outcome[87].

At present time there is some evidence suggesting that bone graft substitutes is suitable in the management of depressed tibial plateau fractures[89]. Patient included in the present thesis have all been treated with either allograft or iliac crest bone graft at the surgeons' digression. There has been no attempt in this thesis, to distinction between grafting materials.

5.7. SOCIOECONOMICS

This thesis showed a social deprivation of patients with bicondylar fractures with 88% of the population belonging to the lower social classes compared with the general population with 46% belonging to the lower social classes[90]. This increased incidence of tibial plateau fractures in the lower social classes with an increased likelihood of deprivation is supported by Court-Brown et. al.[90] who reported a significant increase in the incidence of fractures in the most deprived 10% of the population with most fracture types affected.

Sixty-seven per cent of patients were below the retirement age of 65. Before injury, 50% (N=8) of the patients below 65 years of age were employed. This indicates a substantially higher degree of unemployment in the study group compared with the national general unemployment rate of less than 5%[91]. Twelve months after frame removal, 44% (N=4) of the patients who had been employed prior to the fracture had returned to work. This indicates a high risk of exclusion from employment in the study population following a bicondylar fracture of the tibia. This may among other factors be owed to the social classes of the patients, which largely comprised manual labourers with a low level of education. Unfortunately, no information regarding socioeconomic status has been collected on laterale tibial plateau fractures in this thesis.

The author of this thesis suggested that taking socioeconomic information into account when planning pre- and postoperative treatment methods for bicondylar tilbial plateau fractures is important. Especially when taking into consideration the prolonged treatment period, experienced when treating tibial plateau fractures. Development of special treatment algorithms directed towards this patient group, may improve outcome in the future. However, more research is needed to combined social and health science.

5.8. MENTAL HEALTH

This thesis showed an unexpected high rate of mild to severe depression eight weeks after frame removal on the MDI score for patients with bicondylar tibial plateau fractures. These findings are novel and to the authors' knowledge no earlier studies have reported mental health for bicondylar tibial plateau fractures. The severe nature of the fractures and the long treatment period in combination with a high degree of socioeconomic consequences and significantly worse QOL, may be a contributory factor leading to mental vulnerability in patients treated for a bicondylar fracture. Krappinger et al.[26] supported these findings in a recent study of patients treated with the Ilizarov technique after large post-traumatic tibial bone defects. The study reported a major burden of mental and physical stress for both patients and their relatives. In contrast, Baschera et al.[92] reported no significantly worse SF-12 mental component score compared to a normal population in patients treated with ring fixator after one to nine years' follow-up. The development in mental health for patients with bicondylar fractures of tibial plateau should be a point of further interest in clinical evaluation, treatment and research in the future. Unfortunately, the mental burden on patients treated for a lateral tibial plateau fractures has not been a part of this thesis.

In general, this thesis demonstrates that the treatment of tibial plateau fractures are challenging and that some disability following these fractures, must be expected. This is especially the case for the bicondylar fractures, whereas the lateral tibial plateau patients showed satisfactory radiological outcomes, low levels of pain and showed no gait asymmetries combined with satisfactory patient-reported outcomes.

None the less, there is a need for additional research in this area, both with regards to the surgical treatment modalities, but also combining the surgical interventions with social science and rehabilitation, especially when treating bicondylar fractures.

5.9. STRENGTHS AND LIMITATIONS

The main strength in study I is the unique position of Denmark to do population based studies. With the introduction of the Danish Central Person Register (CPR) in 1968, data regarding age, gender, municipality and related information are stored in the Central Person Register on all residents of Denmark. Furthermore, all patient contacts with hospitals and clinics are registered in the Danish National Patient Register(DNPR) and is required by law[71]. Hospital identification, time of contact, type of contact and data regarding structure and treatment among others are registered[71]. This unique setting enables researchers to access more accurate

information about structure and treatment on both an individual and population based level. The main limitation of study I, due to its retrospective design, is the potential flowed classification of the fractures. A flowed registration in the DNPR would exclude the person from the present study and hence reduce the incidence of tibial plateau fractures.

The main limitations of study II-IV are the observational nature (cross sectional study and prospective follow-up cohort studies) which implies that no conclusions can be drawn from the studies regarding causality. However, all three studies provide important information regarding the outcomes following treatment of tibial plateau fractures and this information will be useful in the generation of hypotheses for future studies.

The strength of Study II-IV is the strict partitioning of patients into lateral fractures and bicondylar fractures. If a difference in the outcomes of patients with laterale and bicondylar fractures exist, the generally mixed setting in many retrospective studies, will mask important information.

A limitation of study II is the lack of participation in the study by 12 of potentially 49 patients. This represent a potential selection bias. This type of limitation is also present in study IV where a loos to follow-up of 5 out of 29 patients during the approximately 19 months observational period, might represent a bias.

The present thesis utilizes several different measures to capture different aspects of the outcomes in patients with tibial plateau fractures. As no attempt to validate the measurement methods on this specific fracture type has been attempted, a potential bias is present. However, other studies on lower limb fractures have utilized the same measurement methods, and the methods has been validated on other lower limb orthopaedic diagnosis.

In general, the small number of participants in study III and IV represent a risk of under-powering.

A strength of study II-IV is the presence of KOOS and Eq5d reference populations, which enables us to compare result with a known group representing the general population. The KOOS reference population is based in southern Sweden and even though many common characteristics between the two countries exists, potential important differences might be present. Furthermore, the use of a reference population drawn from the general population might represent a bias, demonstrated by the findings of study IV, which reported a higher incidence of patients in the lower social classes compared with the general population. This implies, that the possibility of a different pre-injury level compared to the reference populations might exists.

Finally, all but study I is based on a single centre study which might indicate a selection bias indicating that extrapolation of finding from the present thesis should be made with due care.

CHAPTER 6. CONCLUSION

This PhD thesis reported an incidence of tibial plateau fractures of 10.3/100.000/year in a complete Danish regional population.

Study II showed that patients with lateral tibial plateau fractures treated with bone tamp reduction and percutaneous screw fixation at a mean of 5.2 years follow-up showed significant difference in one of five KOOS subscales (Sport) compared to a reference population. Furthermore, satisfactory radiological outcomes were observed.

Furthermore, this thesis suggests that patients treated for a bicondylar tibial plateau fracture treated with a ring fixator demonstrates a level of HRQOL (Eq5d) and knee injury-specific (KOOS) score significantly below established reference populations, both during treatment and at 19 months following injury.

CHAPTER 7. FUTURE PERSPECTIVES

This PhD thesis raises a number of questions regarding the treatment and outcomes of lateral and bicondylar tibial plateau fractures.

In the present thesis a level of patient-reported outcome close to the reference population was observed for laterale tibial plateau fractures. However, clinical experience show a small group of patients, which demonstrate poor patient-reported outcome, despite of no signs of depression, malalignment or osteoarthrosis. The literature states the importance of intraarticular lesions. However, no studies have prospectively attempted to evaluate the importance of intraarticular lesions following lateral tibial plateau fracture and their influence on patient-reported outcomes.

Bicondylar tibial plateau fractures represent a small group of fractures but demonstrate serious morbidity. The importance of soft tissue lesions and their subsequent treatment in combination with bicondylar tibial plateau fractures is still not fully understood. Studies evaluating the importance of these lesions with regards to functional and patient-reported outcomes are needed.

The treatment of bicondylar fractures is frequently prolonged, and the subsequent rehabilitation might stretch more than 6 months. Frequent visits to out patient clinics and physiotherapists might constitute a significant burden on both the patients and relatives mental and economic status. When planning the surgical intervention and subsequent rehabilitation it may be important to take the patients social and economic situation into consideration. A corporation between social science and health science may be important in understanding the best treatment options for patients with bicondylar tibial plateau fractures.

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APPENDICES

Appendix A: Papers I-IV

SUMMARY

This PhD thesis reported an incidence of tibial plateau fractures of 10.3/100,000/year in a complete Danish regional population.

The results reported that patients treated for a lateral tibial plateau fracture with bone tamp reduction and percutaneous screw fixation achieved a satisfactory level of radiological outcomes and a level of health related quality of life (Eq5d) below but not significantly different from the Danish reference population at a mean of 5.2 years follow-up. Furthermore, a knee injury-specific questionnaire (KOOS) reported a level of disability close to a reference population with only the subgroup Sport significantly below the age matched reference population.

The thesis reports a level of health related quality of life (Eq5d) and disability (KOOS) significantly below established reference populations for patients with bicondylar tibial plateau fracture treated with a ring fixator, both during treatment and at 19 months following injury.

In general, the thesis demonstrates that the treatment of tibial plateau fractures are challenging and that some disabilities following these fractures must be expected. Moreover, the need for further research in the area, both with regard to surgical treatment modalities, and combining surgical interventions with social science and rehabilitation is necessary.

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